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RESEARCH PAPER



Key factors for the bicycle use of visually impaired people: a Delphi study

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ABSTRACT

Purpose: This study aims to identify the most important factors that influence the independent bicycle use of visually impaired people in the Netherlands.

Materials and methods: Both visually impaired people and professionals participated in a two-round online Delphi study ($n = 42$). In Round 1 the participants identified the factors which they ranked by relevance in Round 2.

Results: The participants prioritised environmental factors related to the traffic situation, the characteristics of the infrastructure, and weather and light conditions (Kendall's $W = 0.66$). They indicated that the most influencing personal factors are related to personality, traffic experience, and personal background ($W = 0.58$). Glaucoma was ranked as the most relevant ophthalmic condition ($W = 0.74$), while glare was regarded as the most important factor with respect to the visual functions ($W = 0.78$).

Conclusions: The factors provided by this study can be used to optimise the independent cycling mobility of visually impaired people. More research is needed to investigate, both, how and to what extent the mentioned factors influence the cycling behaviour.

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Low vision; visual impairment; cycling; biking; mobility; vision rehabilitation

► IMPLICATIONS FOR REHABILITATION

- The results of this study can be used to set priorities during the rehabilitation and training of visually impaired people who wish to cycle independently.
- Visually impaired cyclists may compensate for the consequences of their visual impairments by taking alternative routes that suit their individual abilities and limitations.
- Since gaining and maintaining self-confidence is important for independent cycling with a visual impairment, practitioners such as mobility trainers should not only focus on cycling-related skills and abilities, but also aim to improve the self-confidence of visually impaired people who wish to cycle.

Introduction

Cycling belongs to the most common modes of transport. However, the frequency of bicycle use varies considerably around the world. In Australia, North America, and the United Kingdom approximately two percent of all trips are made by bicycle, whereas relatively high shares are found in some countries in Europe, such as Denmark (18%) and the Netherlands (26%) [1]. In many places in the world bicycle use for daily transport is being promoted, because of the economic, environmental, and health-related benefits [2–7].


In the Netherlands, cycling belongs to the main modes of transport, especially for distances up to 7.5 kilometres [8]. An average Dutch citizen, cycles to commute (to school or work), to go shopping, and to perform other daily activities [9]. In other words, for most Dutch citizens cycling is important for independent mobility and social participation. Almost every child who lives in the Netherlands learns to cycle at a very young age.

Visually impaired people, i.e., people with permanently reduced vision that cannot be corrected [10], prefer to use modes of transport that are considered by themselves and others as most 'normal' [11]. The Dutch flat landscape and high-quality cycle

infrastructure may be beneficial to the cycling mobility of visually impaired people. For example, many cycle paths are separated from fast motorised traffic and are characterised by a distinctive red colour, which contributes to the visual accessibility. However, whether a visually impaired person is able to cycle in regular traffic does not just depend on the characteristics of the infrastructure or on the visual functioning, but particularly on the individual ability to compensate for the reduced vision.

Dutch centres of expertise for blind and visually impaired people provide training and advice to optimise independent mobility. Rehabilitation programs aim to identify the best mode(s) of transport and compensation strategies suitable for the client's situation. Compensation can be described using Michon's model of driver behaviour [12]. Although this model originally aimed to describe the behaviour of drivers, it is also applicable to cyclists' behaviour [13,14]. Based on the model, cycling-related actions can be classified into three levels: the strategic, tactical, and operational level. The strategic level concerns a cyclist's general plans, including the destination, the route, and the time of departure. Typically, these decisions are not subjected to time pressure and are generally made before a ride. At the tactical level,

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 Supplemental data for this article can be accessed [here](#).

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controlled actions are performed in response to the upcoming circumstances, such as keeping distance to other traffic and approaching an intersection. At this level, cyclists have (a few) seconds to decide and manoeuvre. The actions performed at the operational level aim to control the bicycle at the millisecond level, such as keeping balance, steering, and braking. Experienced cyclists perform the actions at this level automatically, directed by (visual) environmental input [12]. Cyclists can compensate for difficulties experienced at one level by taking specific decisions at another level. Potential risks of cycling with a visual impairment mainly derive from shortcomings at the operational level, because the actions at this level are directed by visual input under high time-pressure. These shortcomings can be compensated for at the tactical or strategic level. For example, if a certain situation requires an emergency brake (operational level), e.g., after a child suddenly crosses the road, a cyclist may create more time to react by reducing speed or maintaining a larger distance to the sidewalk (tactical level). Alternatively, a cyclist may reduce the chance of being exposed to such a situation by choosing a cycling route without primary schools in the vicinity (strategic level).

In the Netherlands, there are no minimum requirements of visual functioning to cycle. Legally, there are no restrictions other than a general law that prohibits people to endanger themselves or other road users [15]. The lack of specific minimum vision requirements may contribute to the independent mobility of visually impaired people, especially to those who are unable to use other demanding modes of independent transport. On the other hand, the scarcity of evidence-based information on this topic complicates the assessment of safe independent cycling with reduced vision.

Partly based on a study conducted in Germany [16], most mobility trainers in Dutch rehabilitation centres currently use a visual acuity below 0.1 (decimal; Snellen notation: 6/60 or 20/200) or a visual field less than 60 degrees as absolute contra-indications for independent cycling. However, there are people with visual capacities below these contra-indications who are able to cycle independently [17,18]. Moreover, there are examples of people with a visual acuity as low as 0.16 (6/38 or 20/125) [19] or homonymous hemianopia [20,21] who are capable to compensate for their visual impairments to safely drive a passenger car. This suggests that the visual contra-indications currently used may unnecessarily discourage visually impaired people from independent cycling.

Additionally, it is unclear which factors besides the visual functioning play a role in the bicycle use of visually impaired people. The available literature mainly focusses on (corrected to) normal vision [22–26] or the influence of infrastructural factors on accessibility or accident rates [27–31]. Connor [32] gives a number of factors that may be of importance, based on his personal experience as a visually impaired cyclist and rehabilitation counsellor. For example, he suggests that the evenness of the road surface and the person's auditory skills are important factors besides the visual functioning. However, there are also indications that other aspects, such as social factors, may play a key role [33].

The present study aims to obtain more insight into which factors affect the independent bicycle use of visually impaired people. The factors are differentiated based on the International Classification of Functioning, Disability and Health (ICF) of the World Health Organization [34]. The ICF is commonly used as a framework to describe health and health-related states in rehabilitation and research [33–35]. Based on this classification, 'the activity' of cycling and its effects on social participation interact with two types of contextual factors: environmental and personal factors [34]. The ICF describes environmental factors as factors

that are external to individuals (e.g., the physical or social environment); whereas personal factors are the individuals' features that are not part of a health condition or health state (e.g., fitness, upbringing, or life events). More knowledge about which environmental and personal factors are important for the cycling mobility of visually impaired cyclists may assist mobility trainers in optimising training and advice. This contributes to the independent mobility and social participation of visually impaired people.

Methods

Design

A Delphi study was conducted to identify the key factors for independent traffic participation of visually impaired cyclists. The Delphi technique [36] is commonly used in healthcare research [37] to "achieve consensus among a group of experts on a certain issue where no agreement previously existed" [38,pp.4]. Delphi studies consist of multiple stages or rounds. Round 1 of a classical Delphi study is characterised by open-ended questions allowing participants to freely generate ideas on the topic [38]. Based on the summarised results of Round 1 a second questionnaire, Round 2, is designed. This second round enables each participant to see how his or her opinion compares with the overall panel's response. Based on this, each participant is asked to reassess, or rank, the issues identified in Round 1 to reach a consensus [39]. Besides its iterative nature, another advantage of the Delphi technique is that the participants' answers are initially unknown to the other participants, which eliminates potential influences of dominant individuals and group pressure [40]. Because of these advantages and the lack of available information on the current topic, the Delphi technique was considered to be the most suitable method. The present study concerns a two-round online Delphi study.

Panel selection

This study aimed to identify the key factors from a broad perspective. Therefore, the sample included (parents of) visually impaired people as well as professionals involved in the mobility of visually impaired people (i.e., scientists, clinicians, and staff members of relevant social organisations). The participants needed to understand and speak the Dutch language. They were recruited based on recommendations of experienced researchers and clinicians, a literature search, and through snowball sampling, which means that participants could recommend other potential participants.

Invitations were emailed to 70 potential participants from across the Netherlands and Flanders. Fifty-two of them confirmed their participation. Round 1 was fully completed by 46 participants (88% of those who confirmed). Forty-two participants fully completed both rounds (81% of those who initially confirmed). Three participants unsubscribed from the study before Round 1 and six participants did not respond. The answers of one participant were excluded from the analyses, because they were incomplete. Both rounds included ten participants with self-reported visual impairment. Table 1 shows the characteristics of the participants included per round.

The participants were informed that their responses would be processed anonymously and that they could withdraw from this study at any time. They were not financially compensated. Ethics approval for this study was provided by the University of Groningen Psychology Ethics Committee.

Table 1. Characteristics of the Participants Included per Round.

	Round 1	Round 2
Participants <i>N</i>	46	42
Gender, male/female <i>N</i>	14/32	12/30
Group % (<i>N</i>) ^a		
Scientists	21.7 (10)	21.4 (9)
Clinicians	37.0 (17)	35.7 (15)
Visually impaired people	19.6 (9)	21.4 (9)
Parents of (a) visually impaired child(ren)	13.0 (6)	14.3 (6)
Staff members of relevant social organization	6.5 (3)	4.8 (2)
None of the above	2.2 (1)	2.4 (1)
Visually impaired % (<i>N</i>)	21.7 (10)	23.8 (10)
Rides bicycle ... % (<i>N</i>)		
Daily	71.1 (33)	73.8 (31)
Weekly	21.7 (10)	21.4 (9)
Monthly	2.2 (1)	–
Less than monthly	4.3 (2)	4.8 (2)

^aThis grouping is based on a question by which the participants indicated in which of the groups they felt they fitted best.

Questionnaires

General structure

Both rounds were created and completed between June 2015 and January 2016 using Qualtrics software [41]. The questions were presented using a high-contrasting, sans serif font to optimise visual accessibility. The participants received a personalised email with a link to the questionnaire. These emails also contained an estimation of the time needed to complete the questionnaire (30–45 min), a link to unsubscribe from the study, and the request to complete the round within two weeks. The participants who did not complete the questionnaire in time received two reminders via email.

The participants received instructions at the beginning of each questionnaire, including our interpretations of the terminology used. We explained that we focussed on visually impaired people who experience hindrance or obstructions in cycling due to reduced eyesight, even if they wear the best glasses or lenses. *Cycling* was described as traffic participation as a cyclist by one-self, without the support of others, on a single-seat bicycle.

The questions of both rounds were sorted into three different parts in line with the ICF [34]. These three parts were: *environmental factors*, *personal factors*, and *visual functions and ophthalmic impairments*. The participants were not explained that the ICF was used as a construct since they were possibly not familiar with the ICF terminology. However, they were provided with interpretations based on the ICF. *Environmental factors* were described as external circumstances, including the physical, material, and social environment, whereas *personal factors* were described as internal circumstances unrelated to visual functioning. Both Round 1 and Round 2 ended with general questions regarding the participants' characteristics and the cycling mobility of visually impaired people in the Netherlands, respectively.

Round 1

The first round aimed to generate a long list of relevant factors. The questions regarding the environmental and personal factors were structured in the same manner. Firstly, two open-ended questions were asked: (1) What environmental circumstances would make it particularly difficult for visually impaired people to use the bicycle and why? (2) What environmental circumstances would make it easier for visually impaired people to use the bicycle and why? These questions were followed by a list of statements starting with: "For visually impaired people an important predictor for bicycle use is ...", followed by an environmental factor, such as "the weather" or "the presence of cycling facilities".

For each statement there was an option available stating: "I don't know". Although this list provided insight into the extent to which the participants agreed with each statement, its main goal was to inspire the participants to answer the open-ended questions as completely as possible. Therefore, the participants were allowed to change their previous answers throughout the questionnaire. The questions regarding the personal factors were asked similarly. However, *environmental circumstances* was replaced with *personal circumstances* and in the list of statements personal factors were given, such as "age" or "upbringing".

In the part regarding visual and ophthalmic impairments, the participants were asked to indicate on a 5-point Likert scale, ranging from –2 (totally disagree) to 2 (totally agree), to which extent they agreed that a visual function (e.g., visual acuity, visual field, or contrast sensitivity) influences the bicycle use of visually impaired people. Each item, representing a visual function, was provided with the option stating: "I don't know". An open-ended question followed regarding what ophthalmic impairments can cause a decrease in bicycle use. After each open-ended question in Round 1, the participants indicated on a 5-point Likert scale how sure they were of their answers, varying from 'Not sure at all' to 'Completely sure'.

Analysis of round 1

Four authors analysed the answers on the Round 1 open-ended questions through thematic analysis [38,42]. First, the factors mentioned by each participant were coded using ATLAS.ti [43], a qualitative data analysis tool. Thereafter, the authors organised related factors into higher-order factors. The analysis was performed inductively as using lists of pre-determined factors would possibly impose limitations on the answers. In case a factor suited more than one higher-order factor the research group discussed the issue to come to an agreement.

The higher-order factors were sorted by the number of participants who mentioned these at least once. With regard to the visual functions, the median levels of agreement were calculated per item to acquire their order of importance. The responses on the items to which the participants indicated they "do not know" or they were "not sure at all" were not taken into account in the analyses to acquire accurate results [44] and to satisfy the requirement of equivalent knowledge and experience [45].

Round 2

In Round 2 the participants ranked, by relevance, the factors for independent cycling with vision impairment generated based on Round 1. The factors generated in Round 1 were presented from most to least frequently mentioned, since the goal was to build towards consensus. There was no option available to exclude a factor from the rankings. After ranking, the participants indicated on a 5-point Likert scale how sure they were of their ranking, varying from 'Not sure at all' to 'Completely sure'.

Analysis of round 2

The levels of agreement between the participants were determined by calculating Kendall's coefficient of concordance (Kendall's *W*). This coefficient indicates the strength of consensus among the participants on a scale of 0 (no agreement) to 1 (complete agreement). Schmidt [46] gives further guidance to the coefficient by interpreting 0.5 as *moderate agreement* and 0.7 as *strong agreement*. Similar to Round 1, the answers of the participants who indicated that they were "Not sure at all" of their rankings were excluded from the analysis.

Table 2. Ranking of Environmental Factors that Influence the Bicycle Use of Visually Impaired People.

Order of importance	Environmental factors related to	Mentioned by participants ^a % (n)	Mean rank ^b (SD)
1	Traffic situation (e.g., amount of traffic; complexity; clarity)	65 (30)	1.98 (0.81)
2	Characteristics of the infrastructure (e.g., obstacles; road surface)	91 (42)	2.36 (2.14)
3	Weather and light (e.g., brightness of sunlight; precipitation)	48 (22)	3.36 (1.17)
4	Characteristics of the social environment (e.g., amount of support; (over)protection)	57 (26)	3.95 (1.67)
5	Characteristics of other traffic participants (e.g., audibility; visibility; speed)	41 (19)	5.07 (1.47)
6	External motivation (e.g., availability of alternative transport modes; necessity of bicycle use)	24 (11)	6.31 (1.69)
7	Characteristics of the bicycle (e.g., bicycle modifications; lamp quality)	30 (14)	6.55 (0.94)
8	Living and working conditions (e.g., living environment; working conditions)	24 (11)	7.10 (1.83)
9	Professional coaching (e.g., bicycle training; educating social environment)	22 (10)	8.33 (1.53)

Kendall's $W = 0.66$.^aNumber of participants (n) who mentioned at least one example of the higher-order environmental factor in Round 1 relative to the participants included in the analysis (n = 46).^bMean rank resulting from Round 2 (n = 42).**Table 3.** Ranking of Personal Factors that Influence the Bicycle Use of Visually Impaired People.

Order of importance	Personal factors related to	Mentioned by participants ^a % (n)	Mean rank ^b (SD)
1	Personality and temperament (e.g., self-confidence; perseverance)	72 (33)	1.61 (1.26)
2	Traffic experience (e.g., cycling experience(s); cycling skills)	70 (32)	3.00 (1.32)
3	Personal background (e.g., age; upbringing)	54 (25)	4.02 (1.64)
4	Personal motivation (e.g., eagerness to cycle; need of independency)	24 (11)	4.78 (2.45)
5	Mental fitness (e.g., response and concentration capacities)	54 (25)	5.20 (1.57)
6	Physical fitness and movability (e.g., motor skills; balance)	37 (17)	5.88 (1.79)
7	Knowledge of environment and traffic (e.g., familiar environment; knowledge of traffic)	26 (12)	6.10 (1.80)
8	Insight into limitations and abilities (e.g., adaptability)	22 (10)	7.27 (2.15)
9	Self-help (e.g., self-reliance; sense of responsibility)	11 (5)	7.85 (2.87)
10	Hearing and sense of smell	22 (10)	9.29 (1.38)

Kendall's $W = 0.58$.^aNumber of participants (n) who mentioned at least one example of the higher-order personal factor in Round 1 relative to the participants included in the analysis (n = 46).^bMean rank resulting from Round 2 (n = 41).

Results

Environmental factors

Round 1 resulted in 67 environmental factors that influence the bicycle use of visually impaired people (see [Supplementary table S1](#) for a full overview). These factors were combined into nine higher-order environmental factors, which the participants ranked in the second round as [Table 2](#) shows. The participants indicated that the three most influencing environmental factors are related to the traffic situation, the characteristics of the infrastructure, and weather and light conditions. Accordingly, examples of these factors mentioned in Round 1 are: the amount of traffic, the quality of the road surface, and the brightness of sunlight. Kendall's W indicates a moderate to strong agreement on the ranking of the environmental factors ($W = 0.66$) among the participants.

Personal factors

In Round 1, the participants mentioned 46 personal factors that influence the bicycle use of visually impaired people (see [Supplementary table S2](#) for a full overview). These factors were combined into 10 higher-order personal factors, which the participants ranked in Round 2 as presented in [Table 3](#). Personal factors that were ranked as the most important are related to personality and temperament, traffic experience, and personal background. Respectively, the factors that were mentioned most frequently in Round 1 were: the level of self-confidence, the amount of cycling experience(s), and age. There was a moderate to strong agreement on the ranking of the personal factors ($W = 0.58$) across the participants (n = 41). One participant (2%) was excluded from the Round 2 analysis of personal factors because, this person was "Not sure at all" of his or her ranking.

Table 4. Ranking of Visual Functions that Influence the Bicycle Use of Visually Impaired People.

Order of importance	Visual function	Round 1		Round 2 Mean Rank ^c (SD)
		Participants ^a % (n)	Median ^b	
1	Glare	93 (43)	1	2.47 (1.83)
2	Need of light / influence of light	96 (44)	1	2.74 (1.45)
3	Visual field (binocular)	93 (43)	1	3.13 (1.70)
4	Contrast sensitivity	96 (44)	1	3.71 (1.75)
5	Acuity of distant vision	93 (43)	1	4.26 (1.83)
6	Light-dark adaptation	93 (43)	1	6.42 (1.62)
7	Metamorphopsia	78 (36)	1	6.79 (1.26)
8	Head positions / head movements	83 (38)	1	8.47 (1.22)
9	Depth perception / binocular vision	96 (44)	0	9.05 (2.32)
10	Eye positions / Eye movements	80 (37)	0	9.21 (1.14)
11	Acuity of near vision	96 (44)	0	10.21 (1.91)
12	Colour vision	93 (43)	-1	11.53 (1.31)

Kendall's $W = 0.78$.^aNumber of participants (n) who were included in the analysis of the visual function relative to the total number of participants in Round 1 ($n = 46$).^bMedian resulting from Round 1 indicating to which extent on a 5-point Likert scale the participants agreed that the visual function is important for bicycle use ($-2 =$ totally disagree, $2 =$ totally agree).^cMean rank resulting from Round 2 ($n = 38$).**Table 5.** Ranking of Ophthalmic Impairments that Cause a Decrease in the Bicycle Use of Visually Impaired People.

Order of ranking of ophthalmic impairments that caused a decrease in the degree of disability impact on people			
Order of importance	Ophthalmic impairment	Mentioned by participants ^a	Mean
		% (n)	rank ^b (SD)
1	Glaucoma	31 (12)	1.54 (1.61)
2	Retinitis pigmentosa	33 (13)	2.50 (0.76)
3	Macular degeneration	33 (13)	2.73 (1.71)
4	Cataract	21 (8)	4.62 (1.39)
5	Hemianopia	10 (4)	4.92 (0.69)
6	Albinism	10 (4)	6.31 (1.09)
7	(Optic) Atrophy	5 (2)	7.08 (1.88)
8	Nystagmus	10 (4)	7.19 (0.94)
9	Aniridia	3 (1)	8.12 (1.58)

Kendall's $W = 0.74$.^aNumber of participants (n) who mentioned the ophthalmic impairment in Round 1 relative to the participants included in the analysis ($n = 39$).^bMean rank resulting from Round 2 ($n = 26$).

Visual functions and ophthalmic impairments

The participants ranked the visual functions as shown in Table 4. They regarded glare, the need of light, and the size of the binocular visual field as the three most influencing visual functions for the bicycle use of visually impaired people. There was a strong agreement on the ranking of visual functions ($W = 0.78$) among the participants ($n = 38$). Four participants (10%) were excluded from the Round 2 analysis of visual functions, because they were "not sure at all" of their rankings. In Round 1, the number of participants who "did not know" to which level they agreed with the statements varied from two (4%) to ten (22%).

Round 1 resulted in nine ophthalmic impairments that may cause a decrease in the bicycle use of visually impaired people (see Table 5). The participants ranked glaucoma, retinitis pigmentosa, and macular degeneration as the most influencing ophthalmic impairments. The participants ($n = 26$) strongly agreed on this ranking ($W = 0.74$). Sixteen participants (38%) were "not sure at all" of their rankings. They were excluded from the Round 2 analysis of ophthalmic impairments.

General questions of round 2

The participants indicated on a 5-point Likert scale, ranging from -2 (poor) to 2 (good), to which extent they believed that during rehabilitation, advice, and training for visually impaired cyclists the environmental and personal factors (as mentioned in this study)

are taken into account. They indicated that the environmental factors are sufficiently considered ($Mdn = 1$, $IQR = 1$, $n = 26$), whereas the personal factors are fairly to sufficiently taken into account ($Mdn = 0.5$, $IQR = 1$, $n = 28$). Similarly, the participants were asked to indicate to which extent the Dutch government considers these factors. The participants indicated that the government insufficiently takes into account the environmental factors ($Mdn = -1$, $IQR = 1$, $n = 34$) and insufficiently to fairly considers the personal factors ($Mdn = -0.5$, $IQR = 1$, $n = 30$).

Discussion

This Delphi study aimed to achieve consensus on the most important factors influencing independent bicycle use of visually impaired people. The participants ranked by relevance the factors they suggested in Round 1. This resulted in the rankings of nine higher-order environmental factors and ten higher-order personal factors. Factors related to the traffic situation, the characteristics of the infrastructure, and the weather and light conditions were ranked as the most important environmental factors. These findings are in line with a study of Pavey et al. [47] in which both crossing roads in busy traffic and poorly maintained or uneven pathways particularly belonged to the difficulties of visually impaired pedestrians. The same study showed that visually impaired people experience low levels of confidence about mobility on foot, particularly while walking in unfamiliar places. This is

also in line with the present study, because personality or temperament (e.g., self-confidence), traffic experience, and personal background were ranked as the most important personal factors. Based on Matthews et al. [48], it seems important to take into account that the overall mobility of visually impaired people is under pressure after the occurrence of an accident that undermines their self-confidence.

The participants ranked glare, the need of light, and the size of the binocular visual field as the three most influencing factors related to visual functions for the bicycle use of visually impaired people. Glaucoma, retinitis pigmentosa, and macular degeneration were ranked as the most influencing ophthalmic conditions. Although these results provide insight into the role of functions and conditions, the ability to cycle independently cannot be predicted based only on this. Similar to operating other vehicles [e.g., 19,49], independent cycling depends on the ability to adequately compensate for the impairment(s).

Future studies should investigate which compensation strategies enable visually impaired people to cycle safely. In terms of Michon's model of driver behaviour [12], the present findings suggest that choosing the most suitable cycling route is an important step in making decisions at the strategic level. For example, visually impaired cyclists may consider taking routes with low traffic, well-maintained cycle paths, or even the lowest number of tree-lined streets that cause sunlight flickering. This is in line with the personal experiences of Connor [32]. Compensating by choosing the most suitable bicycle may have beneficial effects as well. For example, in the Netherlands there is an increasing popularity of pedal electric cycles (pedelecs), which have a small motor that gives pedal assistance up to 25 km/h [50]. Pedelecs particularly improve the mobility of elderly people, because these bicycles require less physical energy. The pedal assistance possibly has additional benefits for visually impaired people as saving physical energy may contribute to visual attention. Similarly, three-wheeled cycles (tricycles) may have additional benefits as they are stable when starting from a standstill position. Dismounting the tricycle when looking before crossing a road is not necessary, which saves time and energy.

We found different levels of agreement regarding the rankings across the participants. The level of agreement among the participants was stronger for the rankings of the environmental factors, the visual functions, and the ophthalmic impairments than for the ranking of the personal factors. Personal factors are known to be difficult for classification, as they are strongly associated with social and cultural differences [34]. Conducting a third round could have increased the level of agreement on the rankings. However, data collection ended after two rounds because of the minimal differences between the presentation order of the factors in Round 2 and the rankings after the analysis. Moreover, conducting more rounds would increase the risk of lower response rates as a result of respondent fatigue [39].

Although using the Delphi method has benefits, including the suppression of group pressure effects and dominant individuals, there were a number of limitations. First, coding the Round 1 responses was a sensitive process. Therefore we tried to correctly understand each participant's answer by taking all his or her other answers into account. However, it cannot be ruled out that some responses were interpreted differently than the participant intended. Secondly, the relation between the higher-order factors possibly affected the ranks in Round 2. For example, factors related to *Personality and temperament* may be subject to influences of factors related to *Personal background*. Therefore, to avoid misinterpretations, in Round 2 the higher-order factors were presented with examples.

Finally, it should be mentioned that the sample used may be biased. Although we used a high-contrasting, sans serif font throughout the questionnaires we do not know whether or not there were invitees who declined participation or did not respond to the invitation for visual accessibility reasons. One participant indicated being hesitant to participate in Round 2, because this participant experienced reading the Round 1 questions as very energy-consuming. The Round 2 answers of this participant were collected by telephone. Furthermore, there were more female participants than male participants. However, there are no indications that this affected the validity of the results.

Conclusions

In this study a panel of 42 participants with various backgrounds participated in an online Delphi study, consisting of two rounds. They identified and ranked the most important factors influencing independent bicycle use of visually impaired cyclists. These rankings can, or perhaps should be used for setting priorities during the rehabilitation or training of visually impaired people who wish to cycle. The longlist as a result of Round 1 may give insight into the areas in which clients make potential gains. Future research should point out both how and to what extent the mentioned factors influence the cycling mobility of visually impaired people.

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